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Status Report

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Soft X-ray Optics by Pulsed Laser Deposition

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A series of molybdenum thin film depositions by PLD have been carried out, seeking appropriate conditions for multilayer fabrication. Green (532 nm) and UV (355 nm) light pulses, in a wide range of fluences, were used. Relatively large fluences (in comparison with Si) are required to cause evaporation of molybdenum. The optical penetration depths and reflectivities for Mo at these two wavelengths are comparable, which means that results should be, and do appear to be similar for equal fluences. For all fluences above threshold used, a large number of incandescent particles is ejected by the target (either a standard Mo sputtering target or a Mo sheet were tried), together with the plasma plume. Most of these particles are clearly seen to bounce off the substrate. The films were observed with light microscopy using Nomarski and darkfield techniques. There is no evidence of large debris. Smooth films plus micron-sized droplets are usually seen. The concentration of these droplets embedded in the film appears not to vary strongly with the laser fluence employed. Additional characterization with SEM and XRD is under way.

Since these Mo films, grown for calibration purposes, have total thicknesses of the order of that of a completed multilayer, one can expect that the reflectivity of a Mo-containing multilayer grown by PLD would be significantly impaired by the droplets, as they essentially obliterate part of the useful area. Analogous results can probably be expected for other heavy metals of interest for this work.

While some of the test Mo depositions have to be repeated, due to doubts as to the stability of the laser output during the longer procedures, it seems appropriate at this juncture to seek ways of reducing particulate incorporation which do not rely on fluence selection. This is more pressing for multilayers fabricated using only one laser, since a suitable fluence for one material is likely unsuitable for the other, very different, one. An approach we will explore is the incorporation of a "buffer" gas (Ar for example) in the chamber. One of the most promising alternatives is the use of high-speed shutters to keep the relatively large, and therefore sluggish, droplets and clusters from reaching the substrate. We intend to do an evaluation of this method, cost permitting.

In spite of the problems mentioned, during this period we have also fabricated our first Mo/Si multilayers. These were produced mainly as a capability test for our system. After correcting some programming errors, performance was as planned. UV light pulses (10 ns) were used, with fluence at the targets of approximately 3 J/cm^2 (power densities of 3 X 10^8 W/cw^2). The substrates were Si wafers, at room temperature, placed 4 cm. from the target plane. Using previous calibrations for Mo and Si, the average deposition rates expected near the plume axis were 0.08 A/pulse and 0.3 A/pulse, respectively. We will continue these Mo/Si and other multilayer depositions during the second year of this project. Direct means of monitoring and recording the laser pulse energy during deposition will be added. This should be very helpful for run rejection when the energies deviate from a set value.

Because of the poor substrate coverage uniformity of the PLD technique, sample characterization as to periodicity and interfacial roughness, usually done by low-angle XRD, will be difficult. For now at least, we will have to rely more on TEM, which will definitely require collaboration with some other laboratory.

In January we carried out, in a very limited manner, tests of a concept which could lead to substantial coverage uniformity enhancement.[1] This involves the use of a negative conic lens, in combination with a converging lens in the beam delivery line in order to focus light into a circle. With knowledge of the plume distribution characteristics, it appears possible to select a circle radius which, for a selected target-substrate distance, will yield much improved thickness uniformity over a central region. Several Si depositions with 532 nm light pulses were done with a configuration which, due mainly to system limitations, was far from ideal. The results were encouraging but inconclusive. With the experience gained, we expect to make a more suitable attempt in the near future. This will require some special tooling, temporary changes in the system chamber, and elimination of hot spots in the laser beam profile.

Reference

1. F.E. Fernandez, "*Method of depositing target material on a substrate and lens for doing same*", Patent Application Serial No. 08/027/191, U.S.Patent and Trademark Office.